

SIGNALING SUBS

Navy submarines must rise to the ocean's surface at preset times to receive radio communications, but such rendezvous can give away their strategic positions. Now subs can stay hidden longer, receiving extremely low frequency radio waves from giant transmitters that issue abbreviated commands. Eventually, subs may get all their signals from orbiting satellites that beam blue laser light deep into the ocean.

By T. A. HEPPENHEIMER
Painting by Jeff Mangiat

The North Atlantic is fearsome in winter. Sleet slants down from thick cloud banks scudding low above the empty gray sea. The torrents slash through windblown spray as the storm raises enormous swells. Hundreds of feet below the surface, a submarine slowly, quietly heads north.

From its polar orbit in space, a satellite shoots a deep-blue laser beam downward. It quickly spreads to form a broad spot. If this were nighttime, the spot would show dimly at the tops of the clouds, but in the early after-

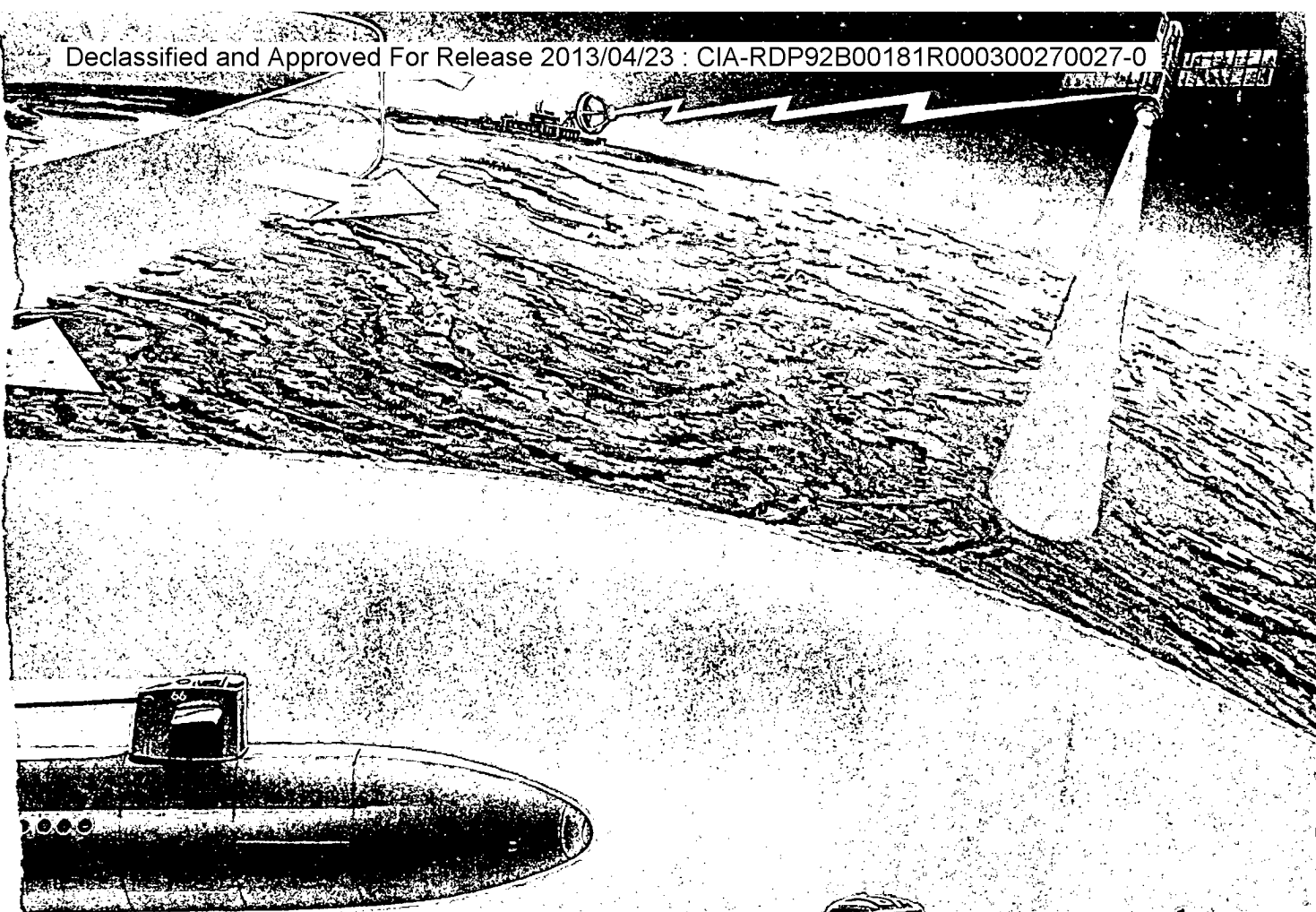
noon the sun's glare hides it. The laser beam scans back and forth, plunging through the churning waves deep into the sea, where it sweeps over the submarine and passes onward.

Aboard the sub, a communications officer watches as her computer terminal lights up. Quickly she sends the coded message to its intended recipient, the ship's executive officer. His own computer soon shows the decoded command: U.S.S. DALLAS, PROCEED TO SECTOR C. He issues a rudder order; the sub slowly turns. Now it will patrol closer to the Soviet Union.

Until recently, subs had to rise to the surface at appointed times to lis-

ten for radio messages from circling airplanes in the older TACAMO (Take Charge and Move Out) system. Now, two new signaling systems will allow subs to receive instructions without interrupting their deep patrols. One, already in operation, is a million-watt-plus extremely low frequency (ELF) radio transmitter that can relay messages to subs throughout the world (see captions, right and next page). Its coded three-letter commands tell subs when and where it's safe to come up for more-detailed messages. The second system, using blue laser light, will relay more-complex signals, making

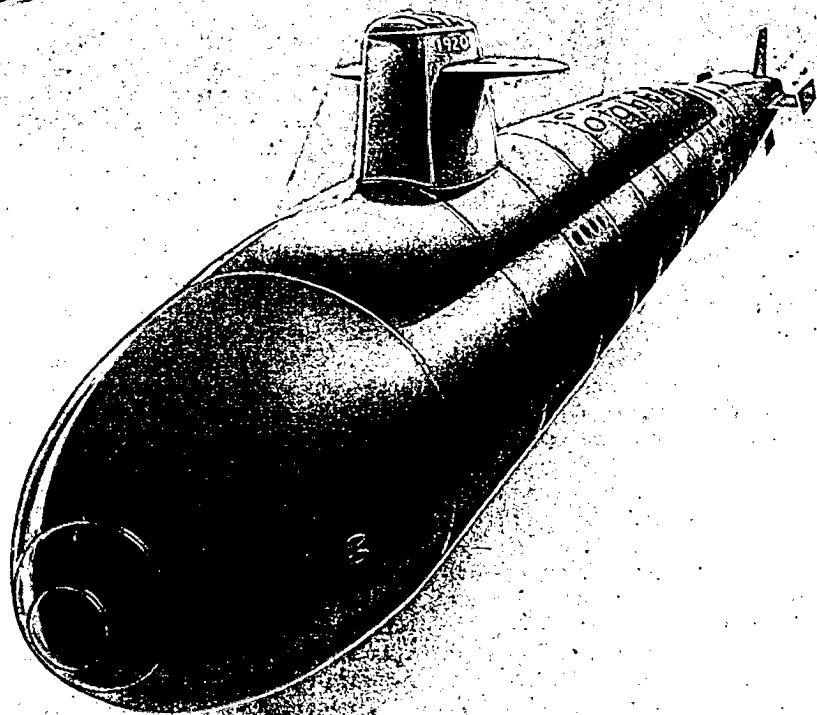
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Ordinary radio waves can penetrate only a few feet into seawater. But ELF radio signals (left) can penetrate hundreds of feet without being absorbed. They have even been picked up 30 feet under the Arctic ice pack. The waves bounce off the ionosphere and strike antennas towed by subs. The signals that emerge from ELF have wavelengths of 2,500 miles—10,000 times longer than the radio waves you pick up with your car antenna.

The blue laser (right) must scan across a large area because the sub's location is a mystery. But the laser flashes 100 or more times a second, so a brief encounter with the sub will suffice. Here's how the laser works: A ground station, airplane, or ship sends a radio signal to the laser satellite. Inside a chamber containing xenon and chlorine, an electric discharge momentarily causes atoms of the two gases to form excited molecules of xenon chloride, called excimers. The excimers quickly break apart, releasing photons that form an intense beam of ultraviolet light. The beam passes through a chamber filled with lead vapor; the vapor absorbs the ultraviolet light and shifts its wavelength to 459 nanometers. This corresponds to a deep-blue color.

The blue beam cuts through the water, striking a receiver aboard the sub. Inside a filter, cesium vapor absorbs photons at the specific wavelength of the laser, then re-emits this energy as photons with near-infrared wavelengths. A photodetector watches for these photons, which could not have penetrated from the surface. Radio signals sent up to the satellite convey information by modulating the laser photon stream.



it possible for subs to stay hidden from enemy detection even longer. In addition, a torpedo-like receiver dubbed RAGU, deployed by sub, has been proposed to relay messages from satellites, eliminating the problems associated with receiving radio signals from aircraft. More about that later.

Submarines spend most of their time at great depths, moving slowly. That way, they emit very little noise while they listen—with sensitive sonar—for other subs [PS, July '83, July '85].

A sub never transmits while it is underway because that would reveal its position. But it must be able to receive incoming radio traffic. Much of this is purely routine: WHEN YOU GET TO POINT B, LOAD 500 POUNDS OF POTATOES AND 50 QUARTS OF OIL. From time to time, subs get more important signals—orders to move to designated locations, or to patrol in a different part of the sea. The new communications techniques are essential for these transmissions:

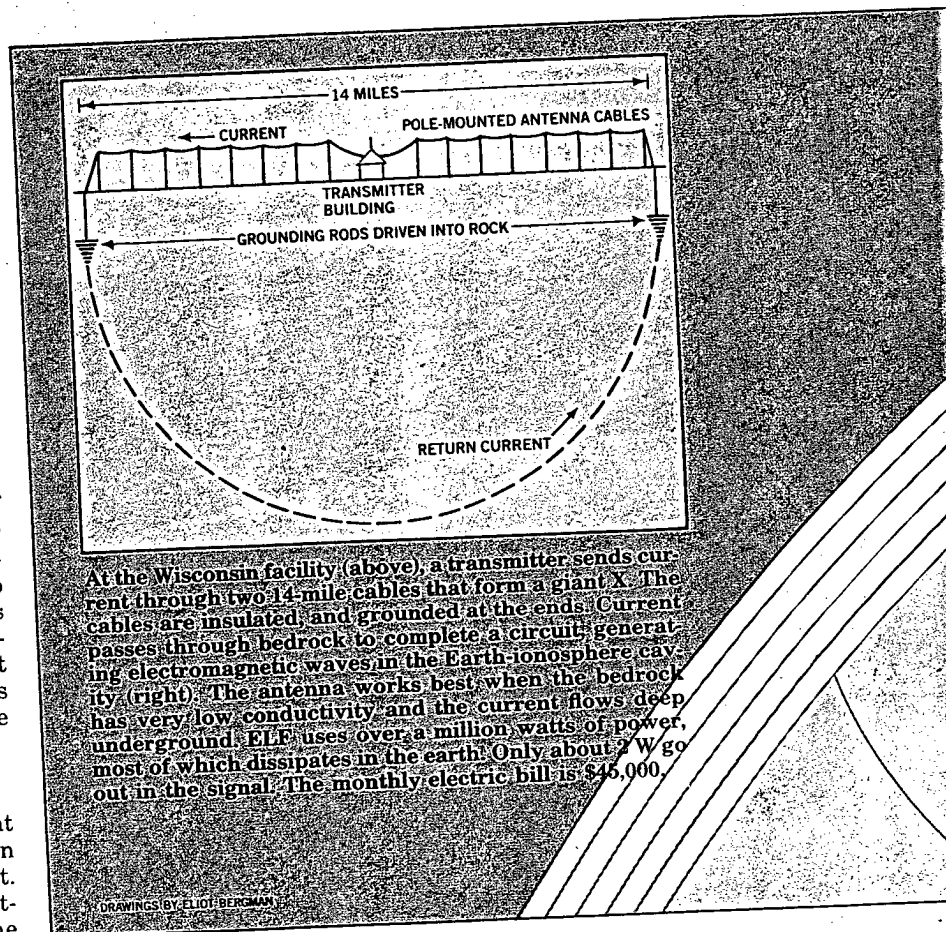
Supersensitive receiver

The blue laser being developed at Northrop Corp.'s Electronics Division in Hawthorne, Calif., is highly secret. The same is true of the blue-laser satellite, called SLCSAT (Submarine Laser Communications Satellite), which is under development at Lockheed Missiles & Space Co. in Sunnyvale, Calif. The Navy fears that if the blue-laser system is not closely guarded, the Soviets may learn the SLCSAT codes. Then they might be able to send false messages to U.S. submarines.

Still, several Pentagon officials have described the new laser in "sanitized" statements distilled from testimony given at secret hearings before Congressional committees. According to Robert Cooper, director of the Defense Advanced Research Projects Agency, a new optical receiver has greatly advanced the laser's usefulness. The laser-beam detector, invented at the University of Arizona, is far more sensitive than its predecessors. It's like "a development in aviation going from a Piper Cub propeller plane to a jet airliner," Cooper declares.

The blue-laser system has evolved from an older proposal based on a longer-wavelength blue-green laser: A large ground-based laser would produce a powerful sea-colored beam, and an orbiting mirror would reflect the beam into the ocean. The original blue-green laser idea was problematic. The beam would spread out as it rose through the atmosphere, and the mirrors would be huge.

In the new blue-laser system, a



radio receiver inside the satellite picks up messages and fires an on-board laser, so the beam comes directly from space. The supersensitive light detector aboard subs will enable satellite lasers with relatively modest outputs to do the job. But the gains, tests, show, would be impressive. Donald Latham, the Pentagon's chief of communications research, says the blue laser provides "a several-hundred-foot increase in the depth achievable."

Here's how a recent field test of the blue-laser system progressed:

It's a clear, bright day off San Clemente, Calif. The submarine *U.S.S. Dolphin* lies beneath the Pacific. Overhead, scarcely visible from the ground, a Sabreliner business jet traces its contrail through the sky, 20,000 to 30,000 feet up. A blue laser beam slants downward, shot from an 80-watt system aboard the aircraft. The beam cuts through the sea and reaches the *Dolphin*, transmitting messages.

"The depths we reached are astonishing—and classified," says a Pentagon official. Bigger lasers are coming. Already, Northrop has built a 400-watt blue laser called EXCEL, which will be able to penetrate hundreds of feet. Still, according to Cooper, the complete system won't be ready until the 1990s.

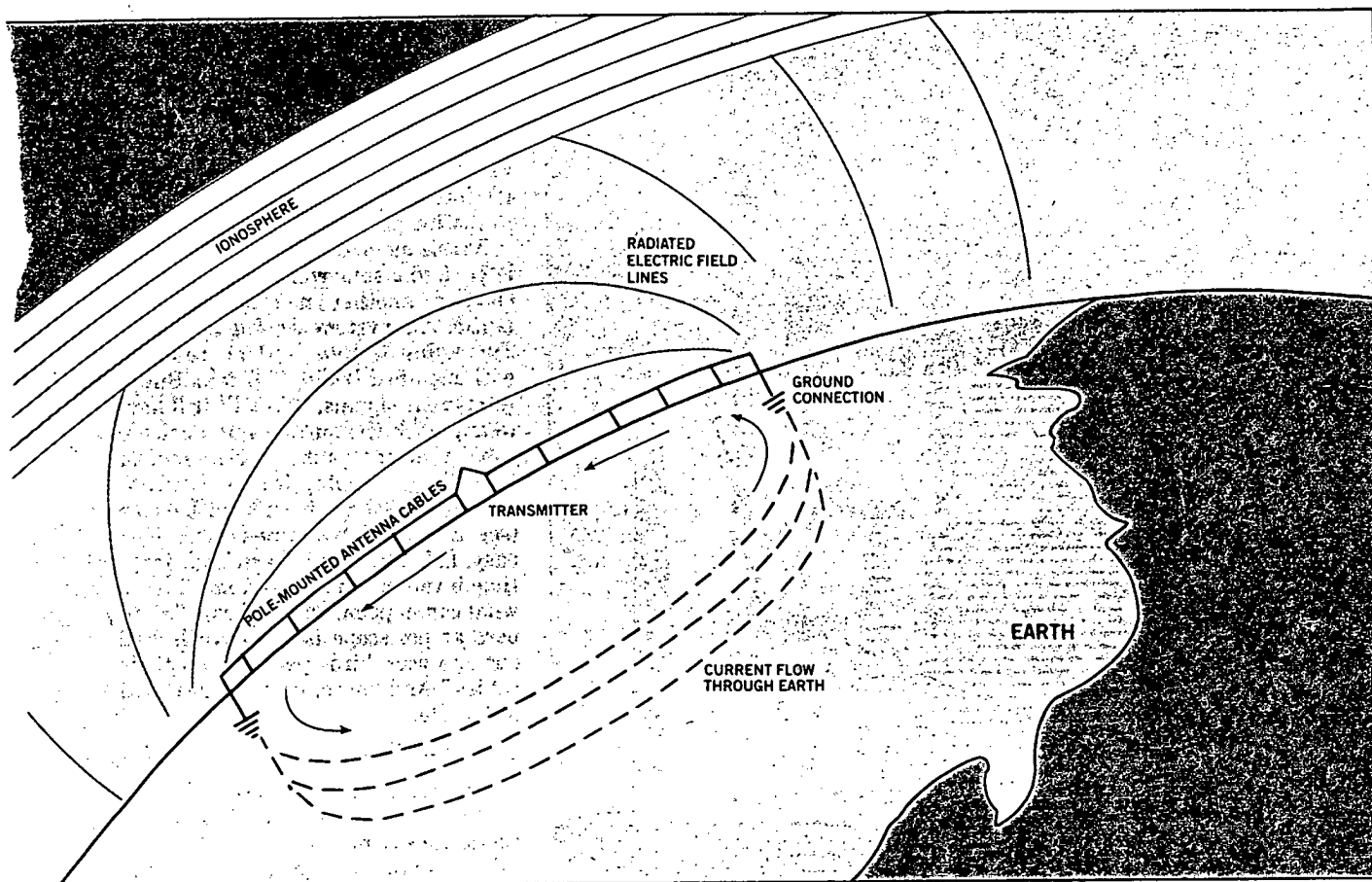
In the meantime, the Navy will rely

on ELF radio transmitters nearing completion amid the forests of upper Michigan and northern Wisconsin. Although the blue laser is cloaked in secrecy, ELF is largely out in the open. To visit its sites, I flew to Marquette, Mich.

Shield rock

"The antennas consist of long cables like those of a power line, running for miles on telephone-like poles," explains Wiley Cress, the naval lieutenant showing me around. The transmitter's 56 miles of stiff braided-wire cable form a huge, ragged letter F on a map. (The shape is based on land availability and has no special significance.) The circuit is completed by the area's bedrock, a dry granite that is part of a formation known as the Laurentian Shield. The Navy chose this site because the rock, which has very low conductivity, forces the current to travel in a deep underground loop (see drawings).

Cress and I drive to K.I. Sawyer Air Force Base nearby, where the ELF control room is located. Radioman 2nd Class Mark Marshman, dressed in naval uniform, greets us. "SUBLANT, the submarine-control center in Norfolk, Va., controls the signal traffic," he states. "They will never let you inside the message center at Norfolk,



but what we have is nearly the same."

Marshman demonstrates the signaling procedure: "We receive teletype messages from SUBLANT, or orders over an encrypted telephone: SEND SUCH-AND-SUCH A MESSAGE FOR TWO HOURS." As he types on a keyboard, the console makes a mechanical clacking sound. "I'm sending a message that this is a training exercise. We don't have the code book. There's no coded message we could send that would order, 'Launch your missiles.' The orders are more like, 'Come up to receive further messages.'"

ELF can also direct course changes. For example, a carrier battle group might be in the Norwegian Sea, close to the Soviet Union. An attack sub rides out ahead, listening for Soviet subs armed with cruise missiles. A storm comes up, and the carrier force changes course. In the old days, the U.S. sub would blithely continue on its path. "I've been in exercises like this, and it's very frustrating," Cress recalls. "The sub could be three hundred miles away by the time he gets the word." But with ELF, the orders can reach the sub in a timely fashion.

Because the Michigan site is not yet operational, the next day Cress and I visit the Wisconsin facility to see a superpowerful transmitter working. The road leads through several small

mining towns. I recall that ELF was the center of considerable controversy for a time: Protesting demonstrators sought to shut it down; environmentalists charged that it would create dangerous radiation; and state governors took the Navy to court [PS, Sept. '69].

Deep in the woods, we turn off on a logging road. A cable strung from wooden poles soon appears overhead. The Wisconsin transmitter features 28 miles of line, set in the shape of an enormous letter X.

Inside the transmitter station is a control room somewhat like that at Sawyer AFB. A row of seven security monitors shows scenes outside the fence. Digital counters flash bright-orange data: CURRENT, 297 AMPS; VOLTAGE, 6,300 VOLTS; FREQUENCY, 76.5 HERTZ. "We're sending the idle message, BCJ," the operator says. BCJ means the system is operating normally but says nothing more.

We walk into a large room with a concrete floor and a number of large gray cabinets. Cress opens the door to the transmitter cabinet, disclosing green circuit boards and blinking green and red lights. There is a loud hum, shifting between higher and lower pitches. "That's the coded signal," remarks Cress. "It takes five minutes to send the message once."

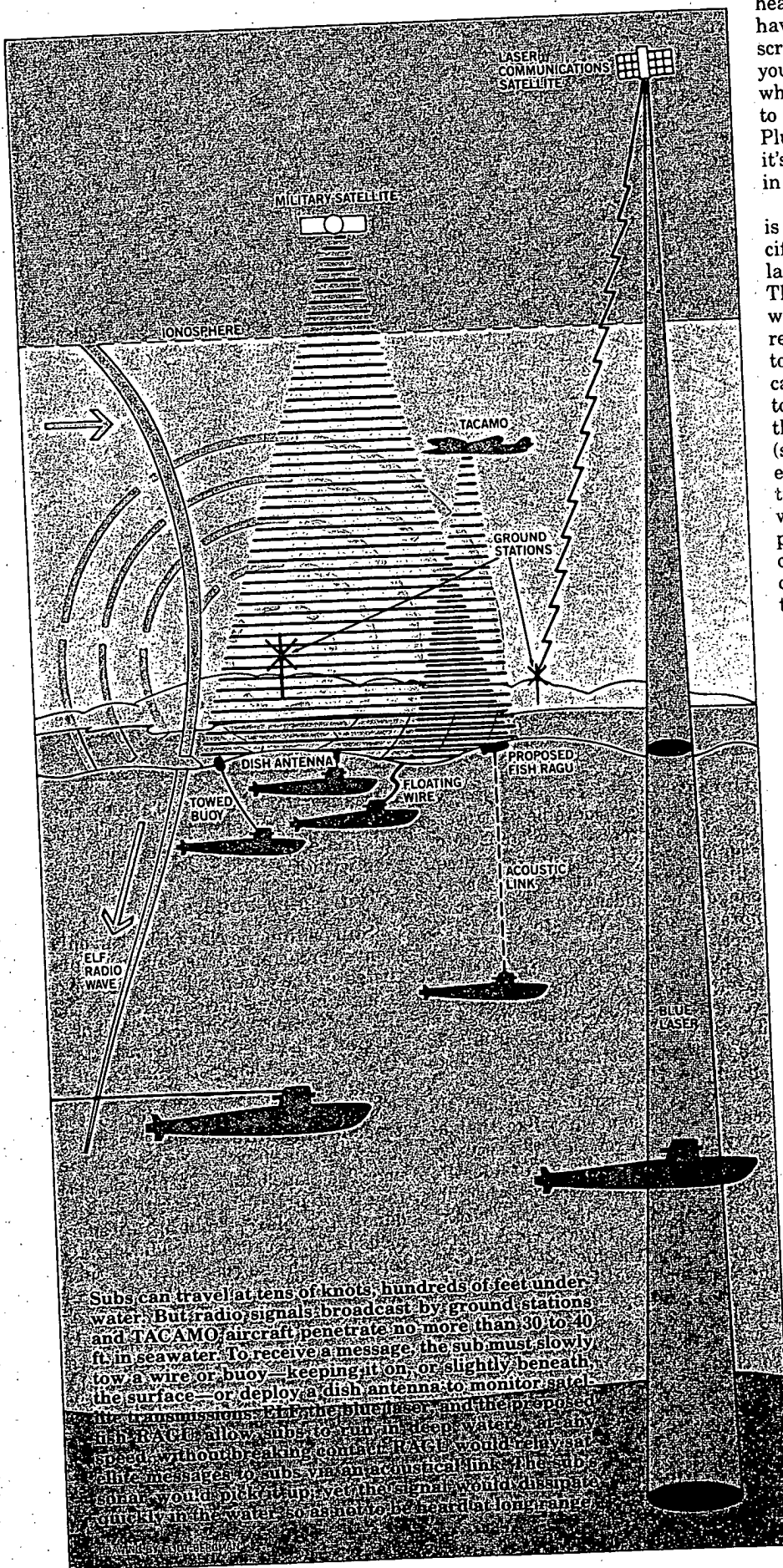
Because the effective transmission power is so low after the radio waves dissipate in the earth, a sub must listen with care.

Flying messengers

Still, within the Navy, ELF can only convey prearranged messages that are listed in the commander's code book. Longer messages are delivered via the TACAMO radio system. TACAMO uses aircraft—modified C-130 transports—that fly in random patterns. When it is time to send a message to the subs, a winch whirs to life, reeling out a transmitting wire nearly five miles long, with a 90-pound weight at the end. The plane banks sharply and flies in a tight circle—the aircraft and its dangling cable resembling an enormous lasso. Because the radio signals cannot reach the ocean depths, subs must use towed cables or buoys to receive messages from TACAMO.

"In the old days, a sub would be carrying out exercises at depth," says Cress. "To receive messages, it would have to come up to one-hundred-thirty-foot depth every twelve hours and stream a cable. This takes time and interferes with normal operations. The sub has to clear its baffles, to start." The baffles are the region behind a sub where its on-board sonar cannot

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hear the sound of a ship. You could have a carrier going with all four screws, and you'd never hear him, so you turn to the left and right to hear what's behind you. Then you come up to periscope depth and look around. Plus, your sub has no keel. In a storm, it's like a hot dog being tossed about in a whirlpool bath."

At this moment, a TACAMO aircraft is in flight somewhere over the Pacific, and another one is above the Atlantic. This system is being upgraded. The aging C-130s will be replaced with modified Boeing 707 jets. But to receive the signals, subs will still have to approach the surface and deploy a cable that serves as an antenna, or tow a buoy—hoping it stays beneath the surface where it will not be seen (see drawing). Sometimes this isn't easy. IBM's Richard Garwin, a long-time inventor of naval systems, knows what can happen. Says Garwin: "Skipper at periscope depth have looked out and seen birds perching on their cables." And buoys, he adds, are hard to handle.

Satellite link

Instead, Garwin proposes what he calls a "fish RAGU." (RAGU stands for Radio Receiving and Generally Useful.) It would be a small torpedo-like device, battery powered and able to swim a few feet below the surface. It would proceed at only a few knots, but subs rarely go faster, because at higher speeds they make more noise and are more easily detected. As Garwin describes it, "You could send the fish a signal by radio: 'Precisely one minute from now a burst of satellite communications will come.' The fish would stop, put up a little antenna that would point to the satellite's location for a second or so, and receive a million bits of information." The fish would then retransmit these messages using a sonar-like acoustic signal, a high-frequency sound directed at the sub.

These systems—the blue laser in the 1990s, ELF today, TACAMO and its upgraded aircraft soon, and the fish RAGU if it should be needed—will make it easier for subs to hide from enemies. Adm. James Watkins, the chief of naval operations, describes the payoff with the help of a story by Mark Twain: "Two bulldogs met. They circled, snarling and growling. Both were bluffing, so nothing happened. And they were about to walk off when one of them opened his mouth. He had no teeth. So the other dog tore him to pieces." In Watkins's view, improved communications are an important way for submarine forces to sharpen their teeth.